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MINUTEMAN STAGE I MOTOR RELIABILITY IMPROVEMENT PROGRAM SURVEIL--ETC(U)
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OGDEN AIR LOGISTICS CENTER

UNITED STATES AIR FORCE

HILL AIR FORCE BASE, UTAH 84406

# FINAL RIP REPORT
# MINUTEMAN STAGE I
# MOTOR RELIABILITY
# IMPROVEMENT PROGRAM
# SURVEILLANCE



PROPELLANT LABORATORY SECTION

MANCP REPORT

NR 379 (77)

OCTOBER 1977

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MMEMP PROJECT M82934C-WNL17514

# MINUTEMAN STAGE I
# MOTOR RELIABILITY
# IMPROVEMENT PROGRAM
# SURVEILLANCE

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(See 1473)

## ABSTRACT

This report contains data and test results from the fourth time testing of the Minuteman Stage I Reliability Improvement Program (RIP) Surveillance. Thiokol (see TWR-7300) had tested and reported on this program for eight years up through 30 June 1973. The responsibility was then turned over to the propellant Laboratory (MANCP) at OO-ALC.

In this report, Thiokol's data with the data from four years of testing in MANCP's laboratory were combined and regression analyses made by MANCP's statistical group.

The purpose of testing is to provide early warning if any serious degradation trends occur in the components being evaluated. The regressions show little or no change in trends from those previously established and are in good agreement with TWR-7300 data. Therefore, based on this analysis the service life of these components may be extended for at least two years beyond the last data point.

This constitutes final reporting on the lab[illegible] testing program on component materials from the RIP Surveillance Program.

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## INTRODUCTION

A. PURPOSE:

Quality assurance testing was conducted by Thiokol for eight years on the RIP program to evaluate the effects of aging on components. Since July of 1973, testing has been performed by the Propellant Laboratory (MANCP) at OO-ALC.

Evaluation of the test data should provide early warning if serious degradation trends occur. Annual evaluation of the components provide data that can be put into engineering reliability and service life predictions. Testing was performed in accordance with MMEMP Project M72632-5MP116P.

B. BACKGROUND:

The Minuteman Stage 1 Reliability Improvement Program (RIP) Surveillance program was conducted from its inception through 30 June 1973 by Thiokol/Wasatch Division under SAMSO direction (TWR-7300, 15 Nov 1974). On 1 July 1973, responsibility for testing was turned over to Ogden Air Logistics Center, Hill Air Force Base, Utah.

1. The primary program objectives were:

a. Demonstrate that the various components and subsystems meet the service life requirements specified by the motor model specifications.

b. Evaluate the storage behavior of components and subsystems so that the start of ageout in the operational force can be predicted or demonstrated in time to take corrective action.

c. Identify and verify failure modes in sufficient time to allow orderly replacement or rework of the missile force.

In addition, major program tasks were to evaluate the storage behavior of the RIP Stage I Minuteman motors under environmental conditions representative of the operational concept, and ultimately to aid in predicting the usable life of the operationally deployed motors.

2. Major tasks were:

a. Subject full scale motors to various simulated operational storage conditions and conduct tests and inspections to determine possible degradation due to storage.

b. Conduct thorough laboratory accelerated aging programs to support the full scale motor program.

c. Provide planning necessary for integrating operational and development motor surveillance programs as data becomes available from operational agencies.

d. Correlate and evaluate all data to establish criteria for determining modes of possible degradation due to aging.

e. Suggest means for reducing or preventing such degradation.

f. Evaluate the effects of aging on motor performance.

g. Provide meaningful estimates of the service life of stage one motors.

3. Component and laboratory specimens were stored at simulated in-situ conditions and elevated temperatures to induce accelerated

aging. Laboratory specimens were selected to evaluate the performance of suspected significant characteristics of the materials under study.

The objectives of the component and laboratory aging effort are:

a. Evaluate the aging characteristics of components materials and interfaces affecting the performance of a complete motor.

b. Evaluate the effects of interaction (by migration of materials that interface in the motor assembly).

c. Correlate accelerated aging results with ambient aging results to allow extrapolation of aging trends when insufficient ambient aging data are available.

d. Provide aging data to predict motor and component storage life.

e. Evaluate test specimens and test techniques for improvement of overall surveillance quality.

Component and laboratory specimens prepared by Thiokol were tested by this laboratory. The results are shown in the figures and are included with the results from TWR-7300 report. The testing at this time does not cover the full range of component testing reported in TWR-7300.

4. The RIP Program is now completed as the specimens that were available for the program have essentially been expended. This document is the final report on the laboratory RIP testing.

## STATISTICAL ANALYSIS

In order to evaluate aging trends, the regression model Y = a + bX was employed to evaluate latest test results with respect to past data. Each regression was plotted to display individual test points with a least squares trend line through them. A tolerance band is given to indicate that at ninety percent confidence ninety percent of any data sampling can be expected to be within this interval. A dashed three sigma (three standard deviation) band parallels the least squares trend line. These bands are extrapolated twenty-four months beyond the age of the test materials the time they were last tested. Regression data at ages eight and upward represent MANCP laboratory testing while previous data were generated by Thiokol.

To obtain an overall view of which materials and test parameters have significant aging trends , a table of significance of regression slopes is given, see Table 1. Statements of significance are given at the five percent level. For those regression parameters having established failure criteria, a one-sided regression analysis was used.

## TEST RESULTS

### A. TENSILE ADHESION:

Tenshear (RS-1) tensile adhesion specimen data shows a statistically significant increase for both the 0° and 45° angle tensile testing (Figures 1 and 2). For both regressions the slope of the curve is gradual. The failure mode for the 0° testing was about 10% cohesive in the propellant and 90% adhesive propellant to liner; and for the 45° testing 100% adhesive propellant to liner.

Regression analysis for RS-4 shows a statistically significant gradual increase for maximum stress (Figure 3). The failure mode was determined by examination of the surface area with the aid of a microscope. The failure mode was about 60% cohesive in the adhesive material, 35% adhesive to the fiber, and 5% fiber failure.

### B. TENSILE STRENGTH:

The regression for RS-12 shows a statistically significant gradual decrease Figure 5. The regressions for RS-5, RS-14, RS-19A and RS-21 do not show a statistically significant trend (Figures 4, 6, 7 & 8).

### C. ELONGATION:

RS-5, RS-12 and RS-19A show no statistically significant trends (Figures 9 thru 11). RS-21 shows a statistically significant gradual increase (Figure 12).

## CONCLUSIONS

The program objectives were to evaluate component and laboratory specimens stored at simulated in-situ conditions and elevated temperatures. The following conclusions are results derived from laboratory testing and analyses.

a. The component materials show little or no aging trends in laboratory testing. From this same testing and visual examination little or no aging is evident in the interfaces. From the analysis of laboratory tesing, aging of the component material and interfaces would not affect motor performance at this time, however, evaluating whole motor performance requires engineering input and judgement.

b. Migration of material and interaction of material at the interfaces was not detected with the component materials tested.

c. There were not sufficient specimens available to run both the accelerated and ambient aging tests. Only ambient testing was done; therefore, a correlation could not be accomplished.

d. The regressions show little or no change in trends and are in good agreement with TWR-7300 data. Therefore, the service life of these components may be extended for at least two years beyond the last data point.

e. The test specimens were satisfactory except for specimens RS-19A and RS-21. Specimens RS-19A and RS-21 were very soft and it was very difficult to hold them in the jaws. This type specimen should be bonded to wood or metal end tabs and an appropriate jaw used.

## RECOMMENDATIONS

Since this is the last time for testing on the RIP program it is recommended that component testing be started as soon as possible from motors in the dissection program. It is expected that the new dissection of motors will start in the first part of 1978. Data from this new dissection program should be correlated with the data previously obtained in the RIP program and other dissected motor data.

TABLE 1

Significance of Regression Slopes

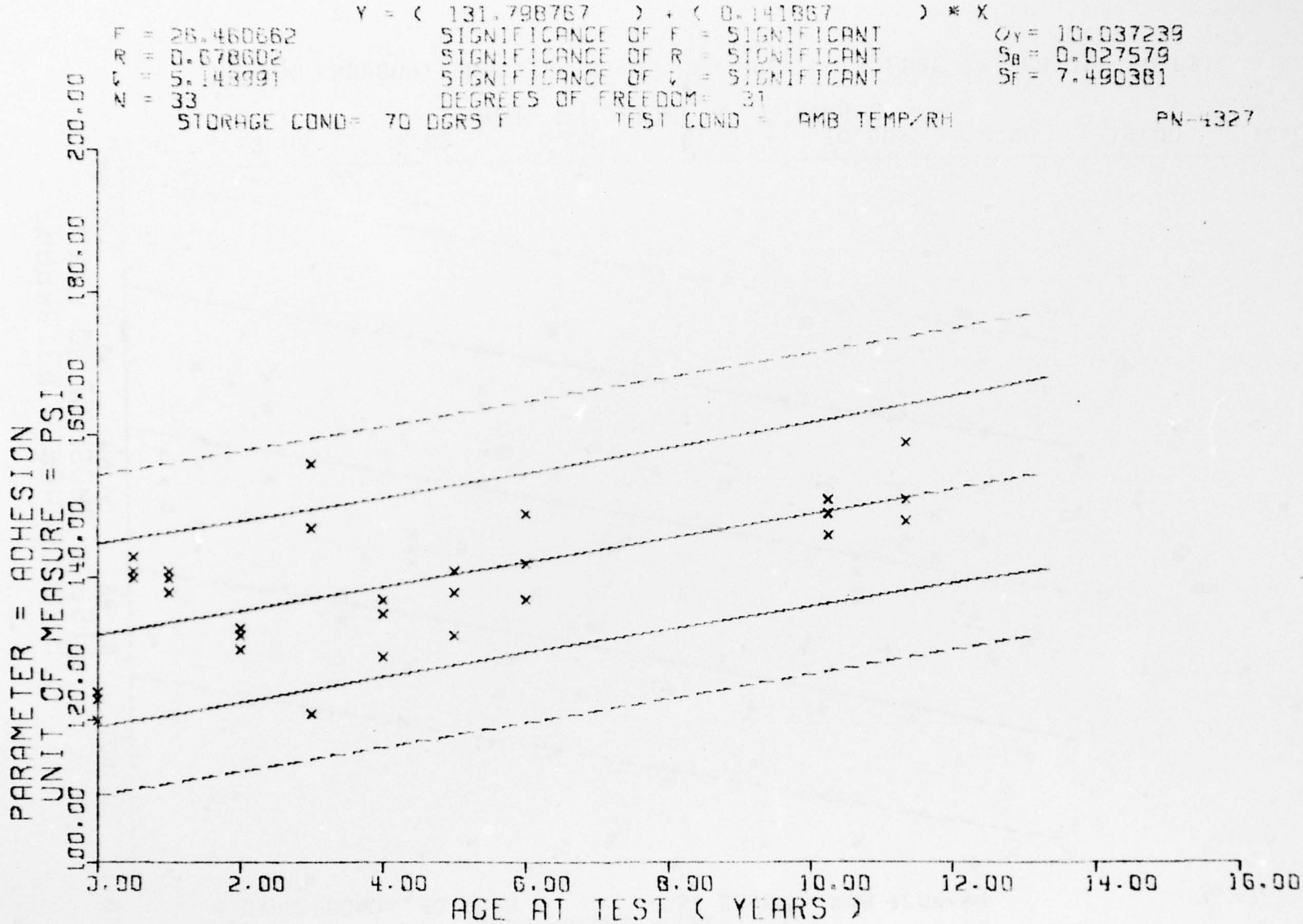
| | | Slope | Significance of Slope | t-Value | DF |
|---|---|---|---|---|---|
| RS-1 | Adhesion at 0 deg. | + | S* | 5.14 | 32 |
| RS-1 | Adhesion at 45 deg. | + | S* | 3.63 | 32 |
| RS-4 | Tensile adhesion (SM) | + | S* | 2.03 | 55 |
| RS-5 | Tensile strength (SM) | + | NS | 0.59 | 80 |
| RS-12 | Tensile strength (SM) | - | S | 2.12 | 105 |
| RS-14 | Tensile strength (SM) | - | NS | 0.01 | 36 |
| RS-19A | Tensile strength (SM) | - | NS* | 0.32 | 61 |
| RS-21 | Tensile strength (SM) | + | NS | 1.51 | 103 |
| RS-5 | Elongation (er) | + | NS | 0.92 | 59 |
| RS-12 | Elongation (er) | - | NS | 1.23 | 88 |
| RS-19A | Elongation (er) | + | NS | 0.52 | 72 |
| RS-21 | Elongation (er) | + | S | 3.37 | 87 |

* Single sided regression analysis employed when a failure criteria is used.

DF = Degrees of freedom

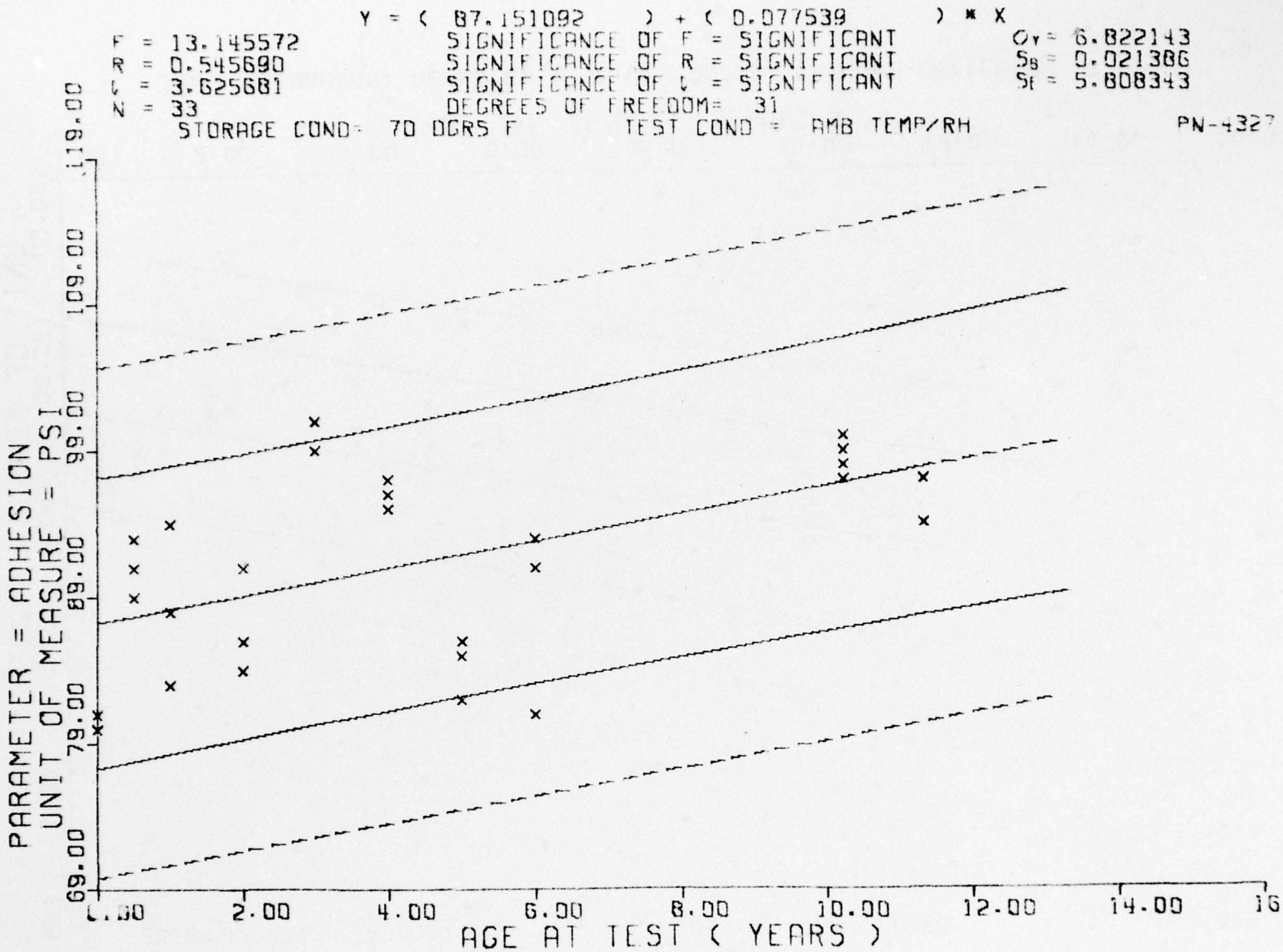
S = Significant

NS = Not significant



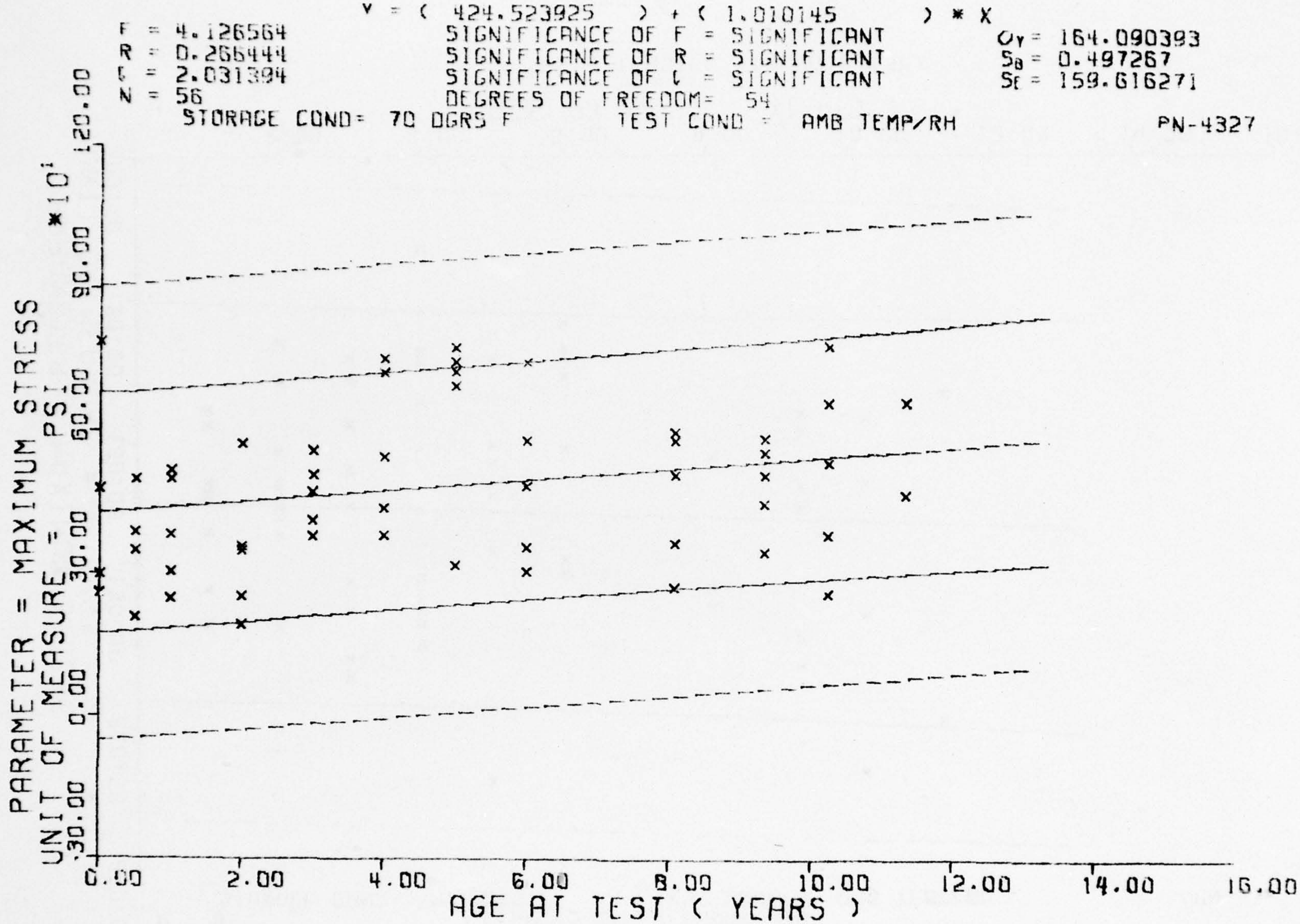

RS-1 (TENSHEAR) ADHESION AT 0 DEG ANGLE. FAILURE CRITERION. (0 PS)

**Figure 1**




RS-1 (TENSHEAR) ADHESION AT 45 DEG ANGLE. FAILURE CRITERION: 10 PSI

**Figure 2**

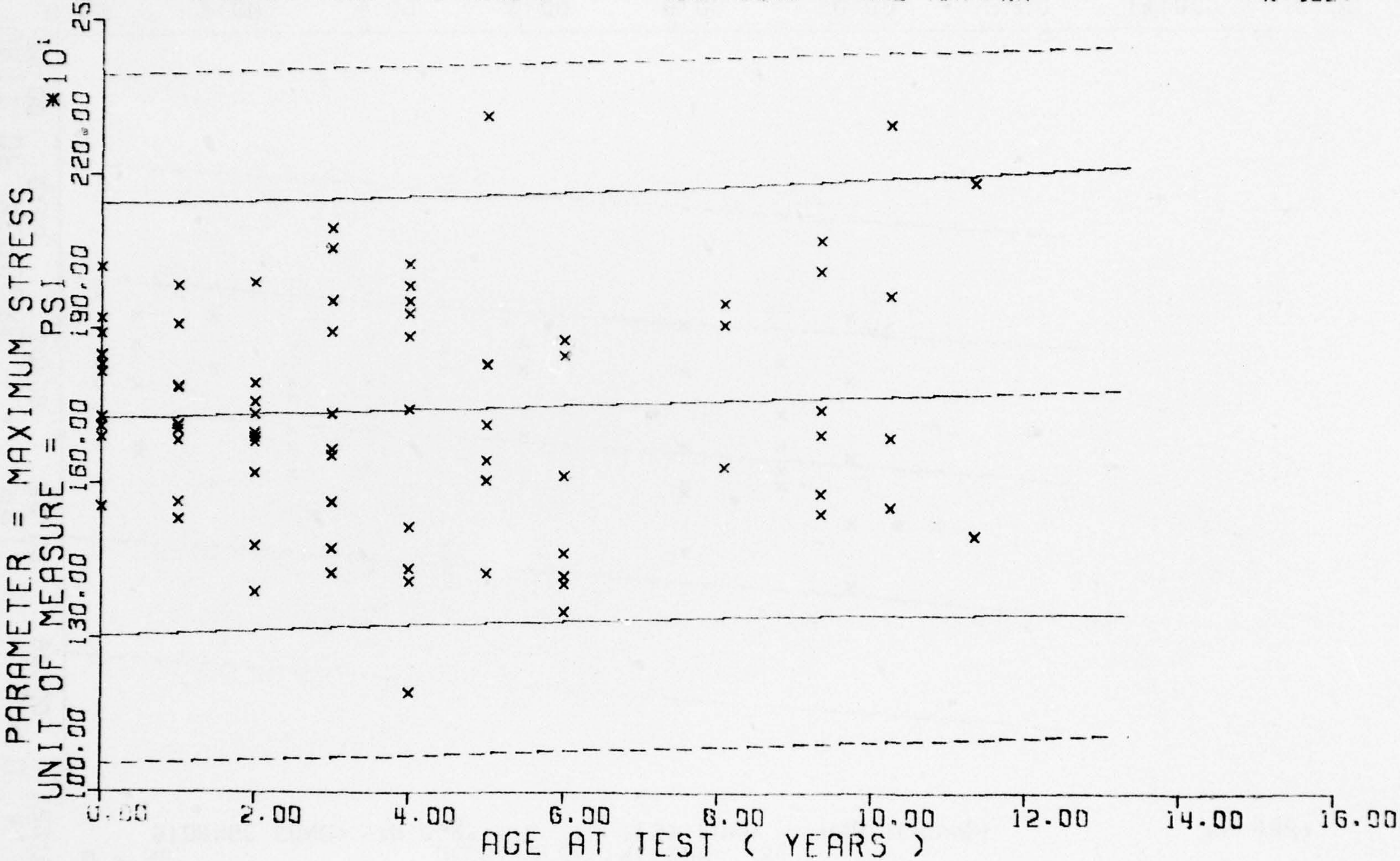



RS-4 TENSILE ADHESION (SM). FAILURE CRITERION: 25 PSI

**Figure 3**

Y = ( 1722.086914 ) + ( 0.380530 ) * X

F = 0.343610  SIGNIFICANCE OF F = NOT SIGNIFICANT  $\sigma_Y$ = 222.106140
R = 0.065808  SIGNIFICANCE OF R = NOT SIGNIFICANT  $S_B$ = 0.649166
t = 0.586183  SIGNIFICANCE OF t = NOT SIGNIFICANT  $S_E$ = 223.022949
N = 81  DEGREES OF FREEDOM= 79
STORAGE COND= 70 DGRS F  TEST COND = AMB TEMP/RH  PN-4327




RS-5 TENSILE STRENGTH (SM)

**Figure 4**

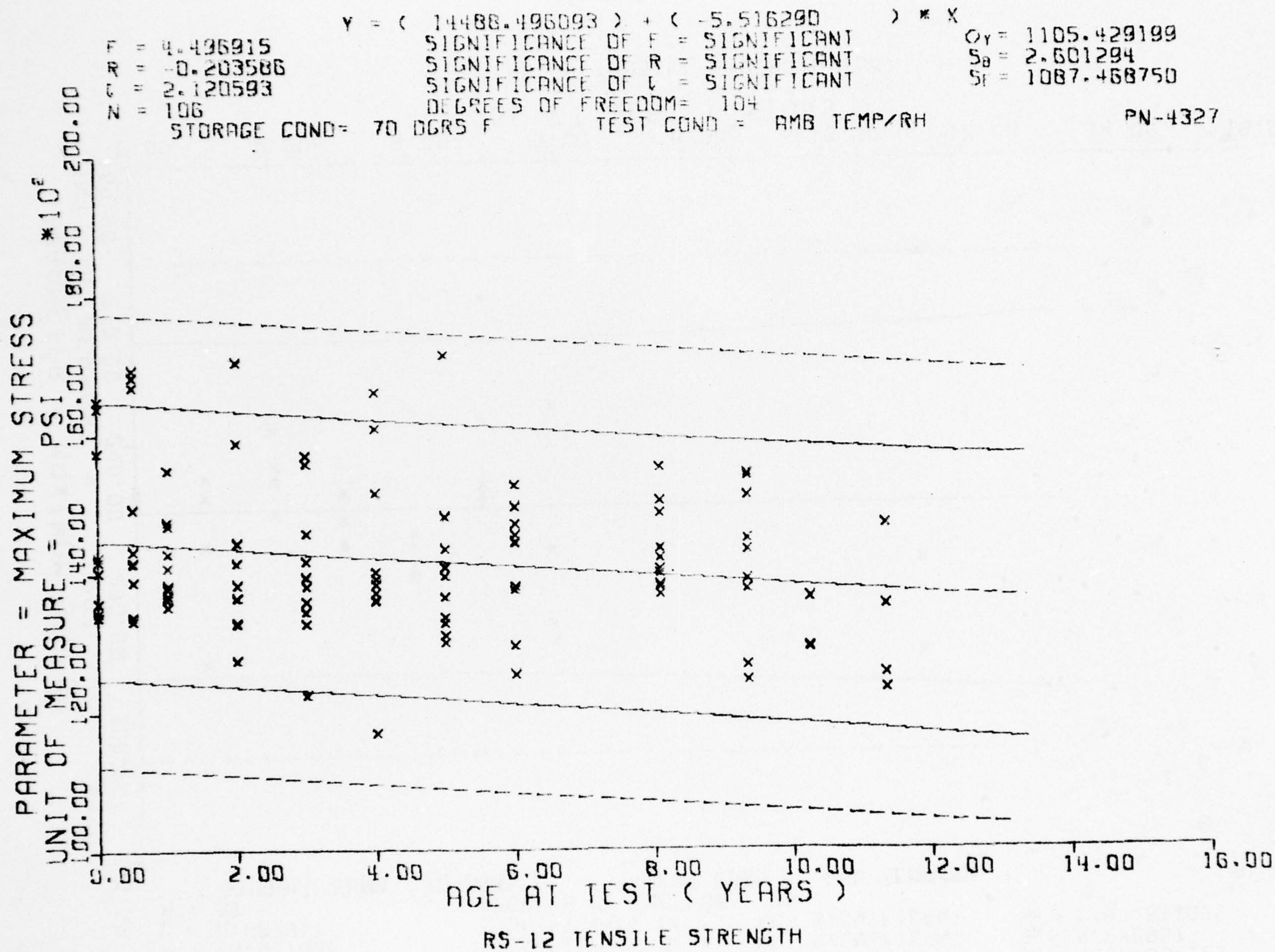

Y = ( 14488.496093 ) + ( -5.516290 ) * X
F = 4.496915
R = -0.203586
ℓ = 2.120593
N = 106
SIGNIFICANCE OF F = SIGNIFICANT
SIGNIFICANCE OF R = SIGNIFICANT
SIGNIFICANCE OF ℓ = SIGNIFICANT
DEGREES OF FREEDOM= 104
σY = 1105.429199
Sβ = 2.601294
Sr = 1087.468750
STORAGE COND= 70 DGRS F
TEST COND = AMB TEMP/RH
PN-4327
PARAMETER = MAXIMUM STRESS
UNIT OF MEASURE = PSI
*10²
100.00
120.00
140.00
160.00
180.00
200.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST ( YEARS )
RS-12 TENSILE STRENGTH

**Figure 5**

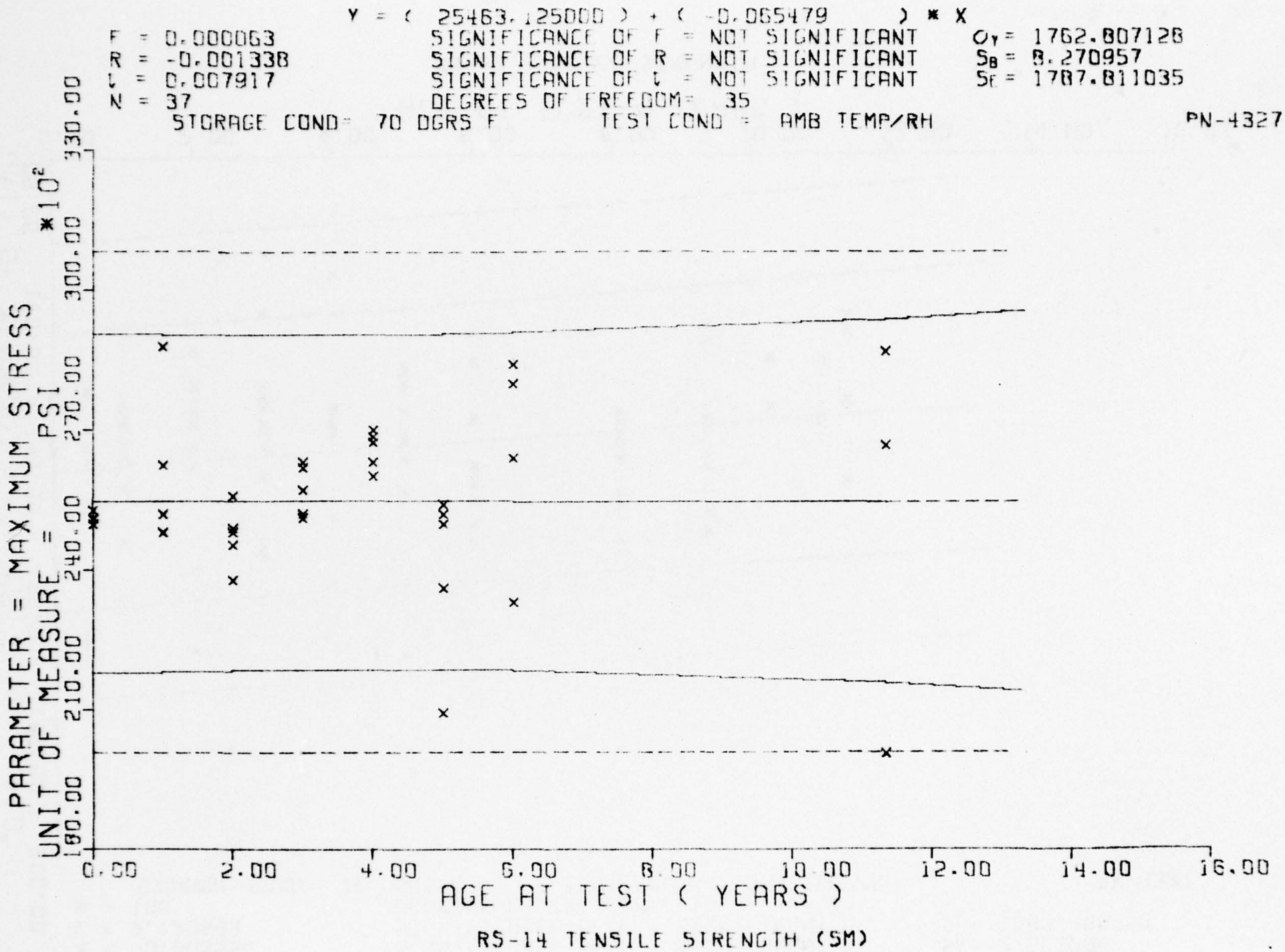
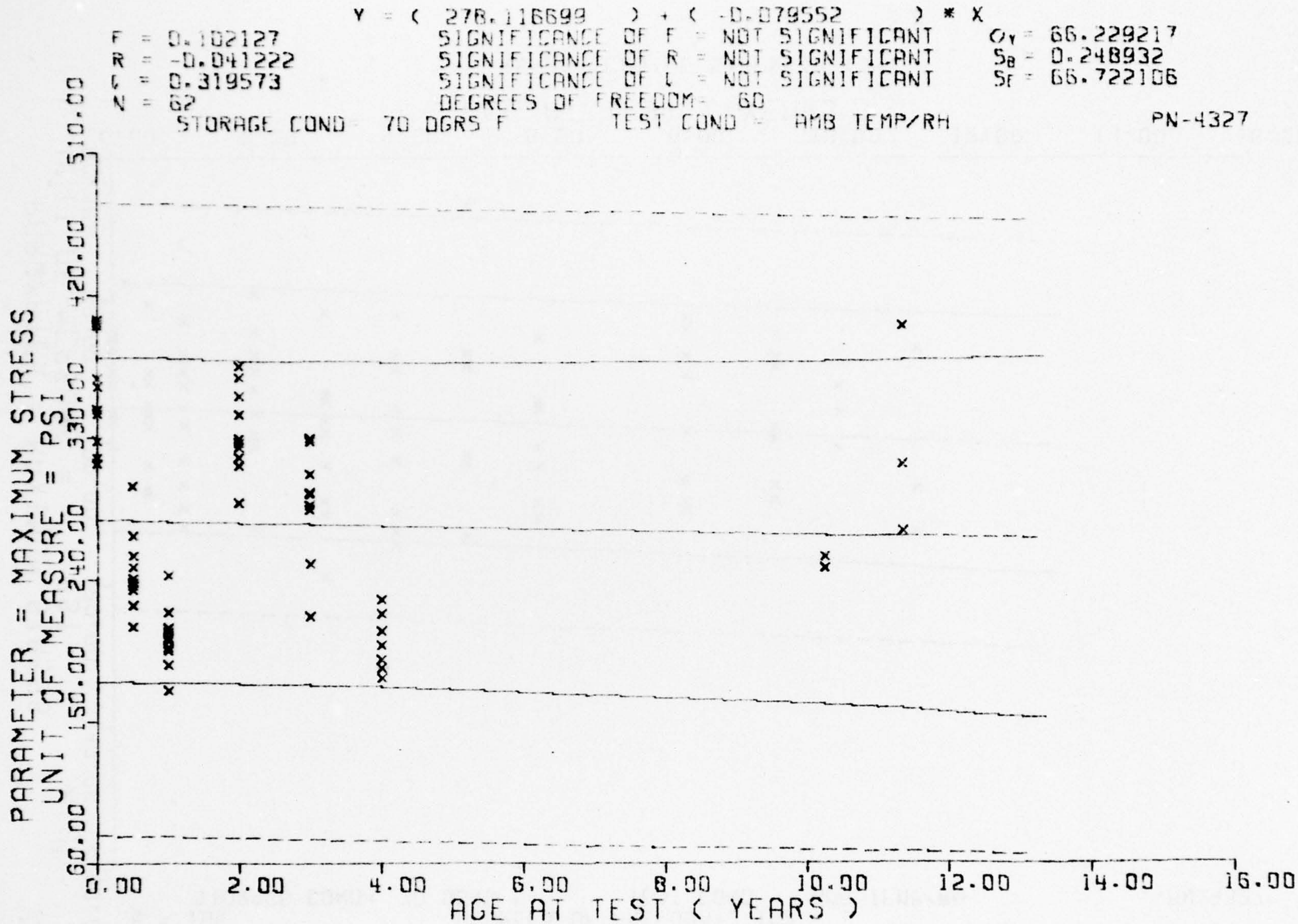

Y = ( 25463.125000 ) + ( -0.065479 ) * X
F = 0.000063
R = -0.001338
ι = 0.007917
N = 37
SIGNIFICANCE OF F = NOT SIGNIFICANT
SIGNIFICANCE OF R = NOT SIGNIFICANT
SIGNIFICANCE OF ι = NOT SIGNIFICANT
DEGREES OF FREEDOM= 35
σY = 1762.807128
SB = 8.270957
SE = 1787.811035
STORAGE COND= 70 DGRS F
TEST COND = AMB TEMP/RH
PN-4327
PARAMETER = MAXIMUM STRESS
UNIT OF MEASURE = PSI
*10²
330.00
300.00
270.00
240.00
210.00
180.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST ( YEARS )
RS-14 TENSILE STRENGTH (SM)

**Figure 6**




RS-10A TENSILE STRENGTH (SM). FAILURE CRITERION: 10 PSI

**Figure 7**

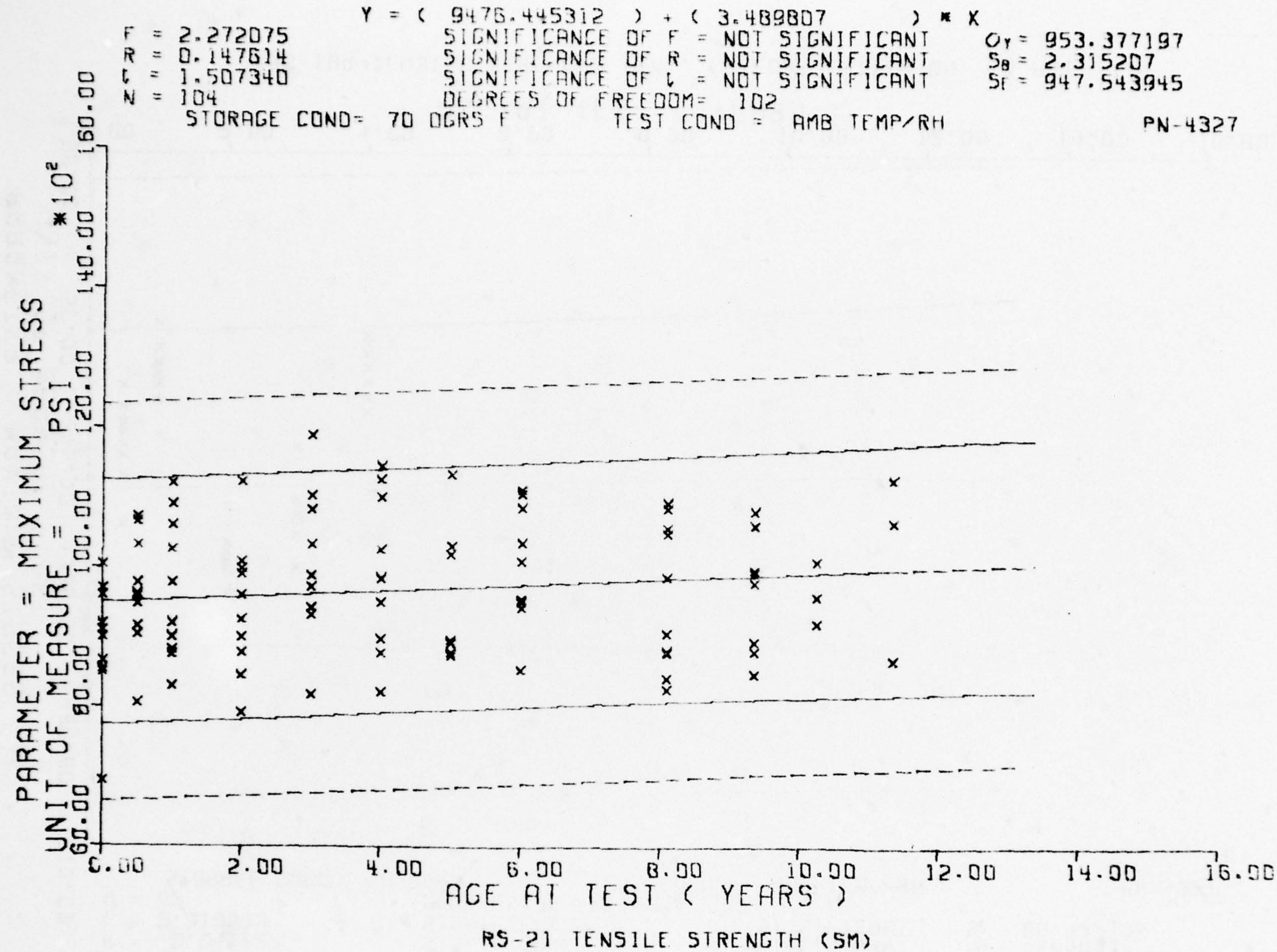
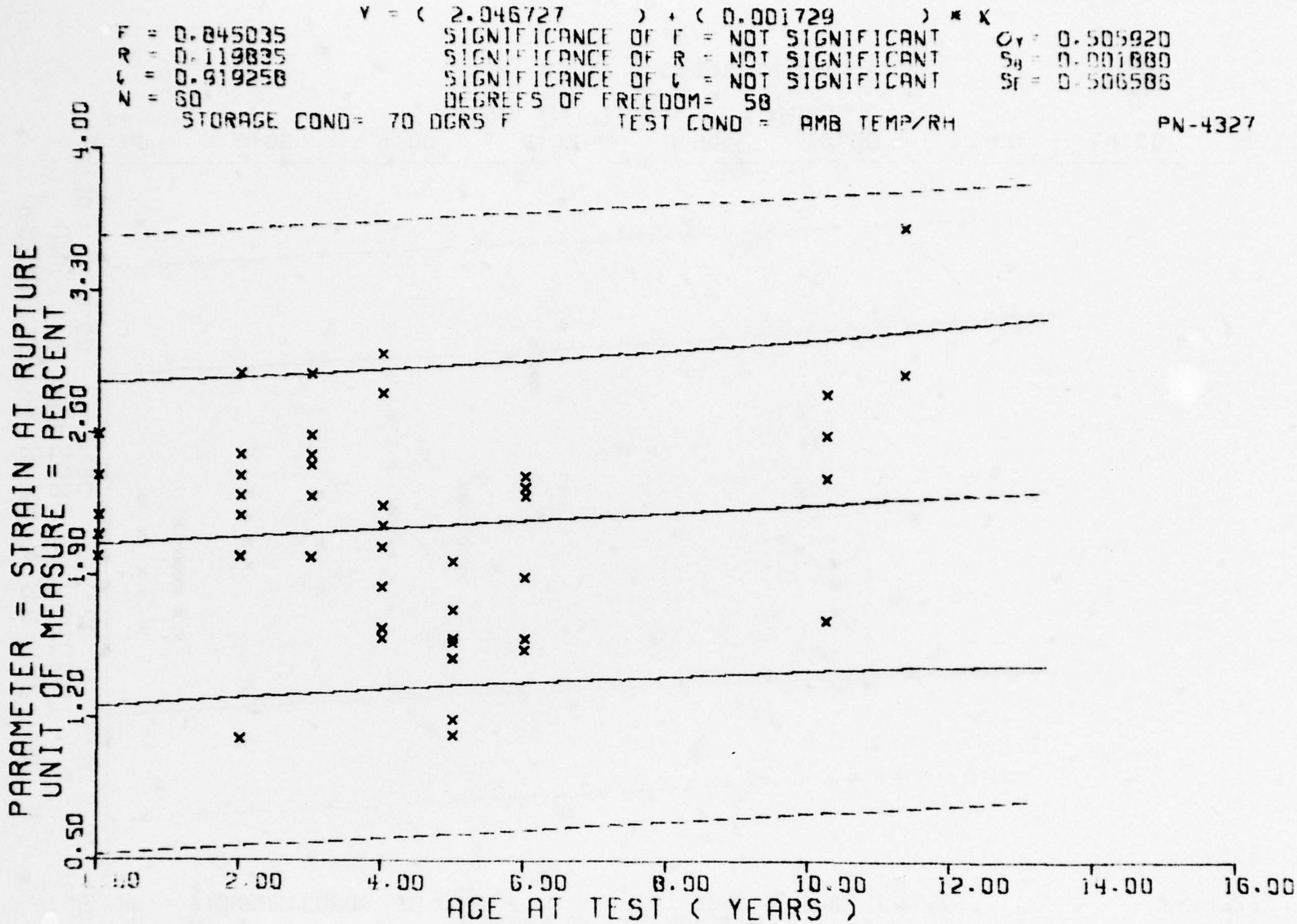

Y = ( 9476.445312 ) + ( 3.489807 ) * X
F = 2.272075
R = 0.147614
t = 1.507340
N = 104
SIGNIFICANCE OF F = NOT SIGNIFICANT
SIGNIFICANCE OF R = NOT SIGNIFICANT
SIGNIFICANCE OF t = NOT SIGNIFICANT
DEGREES OF FREEDOM= 102
σY = 953.377197
SB = 2.315207
SE = 947.543945
STORAGE COND= 70 DGRS F
TEST COND = AMB TEMP/RH
PN-4327
PARAMETER = MAXIMUM STRESS
UNIT OF MEASURE = PSI
*10²
60.00
80.00
100.00
120.00
140.00
160.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST ( YEARS )
RS-21 TENSILE STRENGTH (SM)

**Figure 8**




RS-5 ELONGATION (ER). FAILURE CRITERION. 0.36 PERCENT STRAIN

**Figure 9**

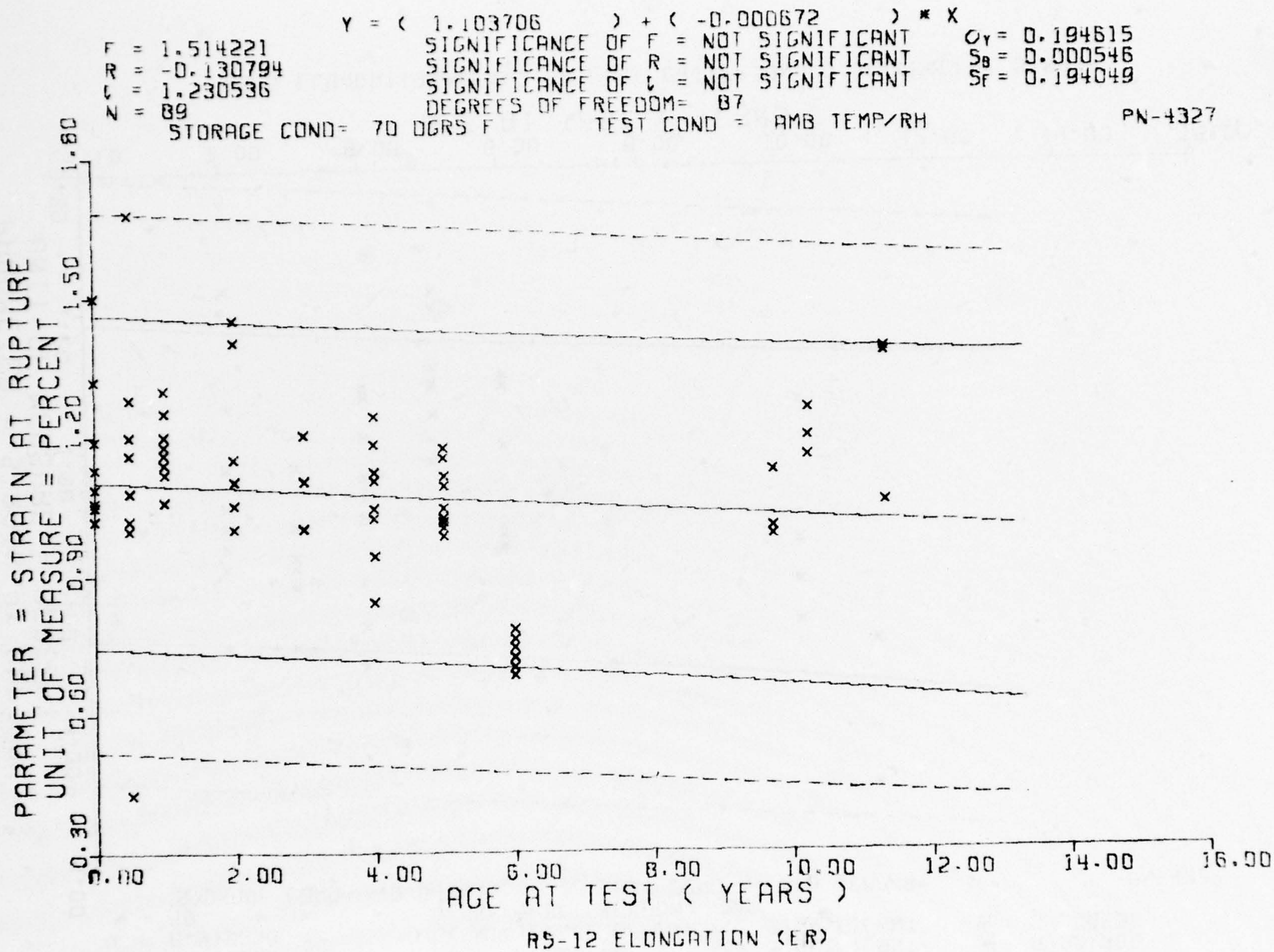
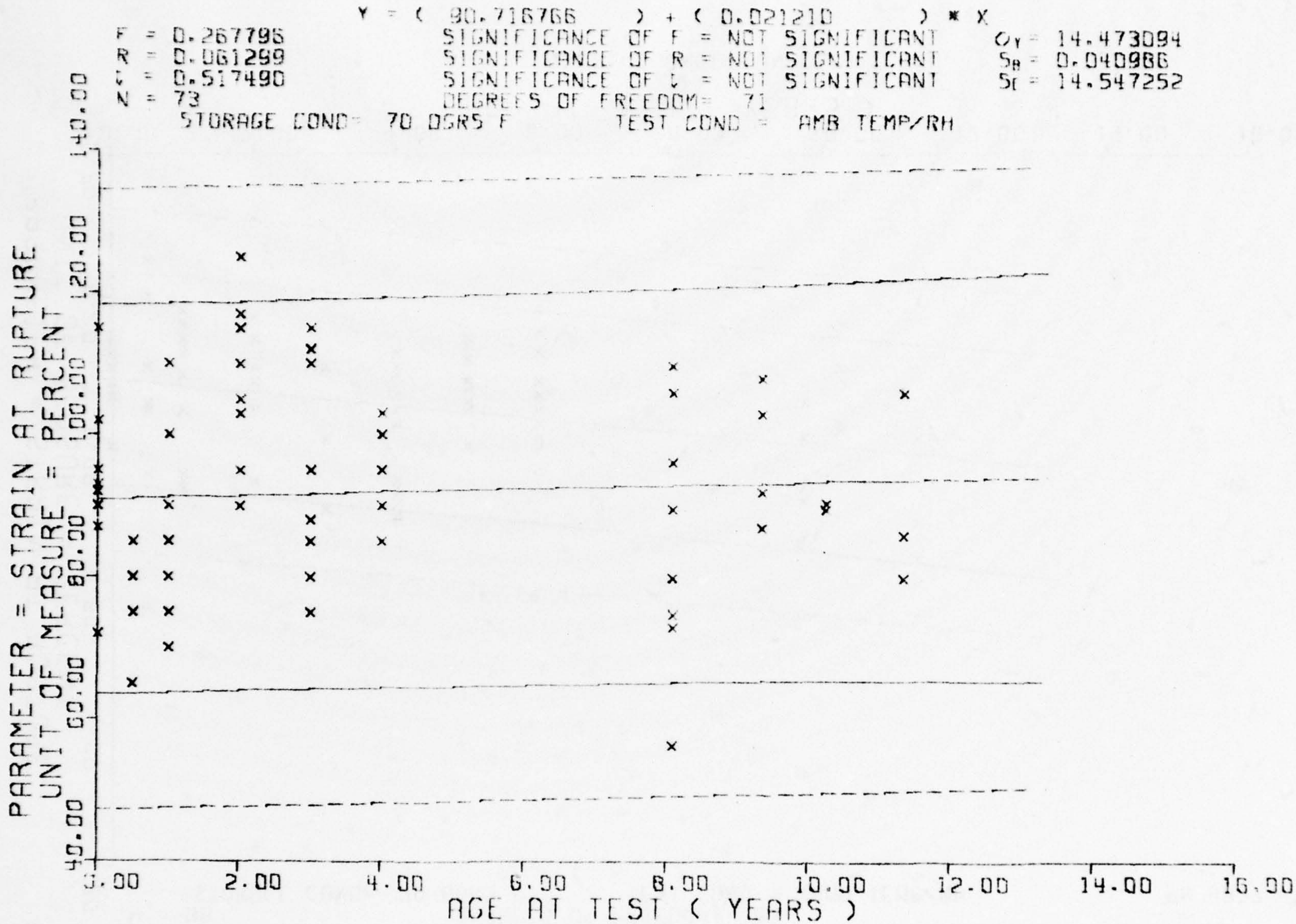

Y = ( 1.103706 ) + ( -0.000672 ) * X
F = 1.514221
R = -0.130794
t = 1.230536
N = 89
SIGNIFICANCE OF F = NOT SIGNIFICANT
SIGNIFICANCE OF R = NOT SIGNIFICANT
SIGNIFICANCE OF t = NOT SIGNIFICANT
DEGREES OF FREEDOM= 87
σY = 0.194615
SB = 0.000546
SF = 0.194049
STORAGE COND= 70 DGRS F
TEST COND = AMB TEMP/RH
PN-4327
PARAMETER = STRAIN AT RUPTURE
UNIT OF MEASURE = PERCENT
1.80
1.50
1.20
0.90
0.60
0.30
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST ( YEARS )
RS-12 ELONGATION (ER)

Figure 10




RS-19A ELONGATION (ER)

**Figure 11**

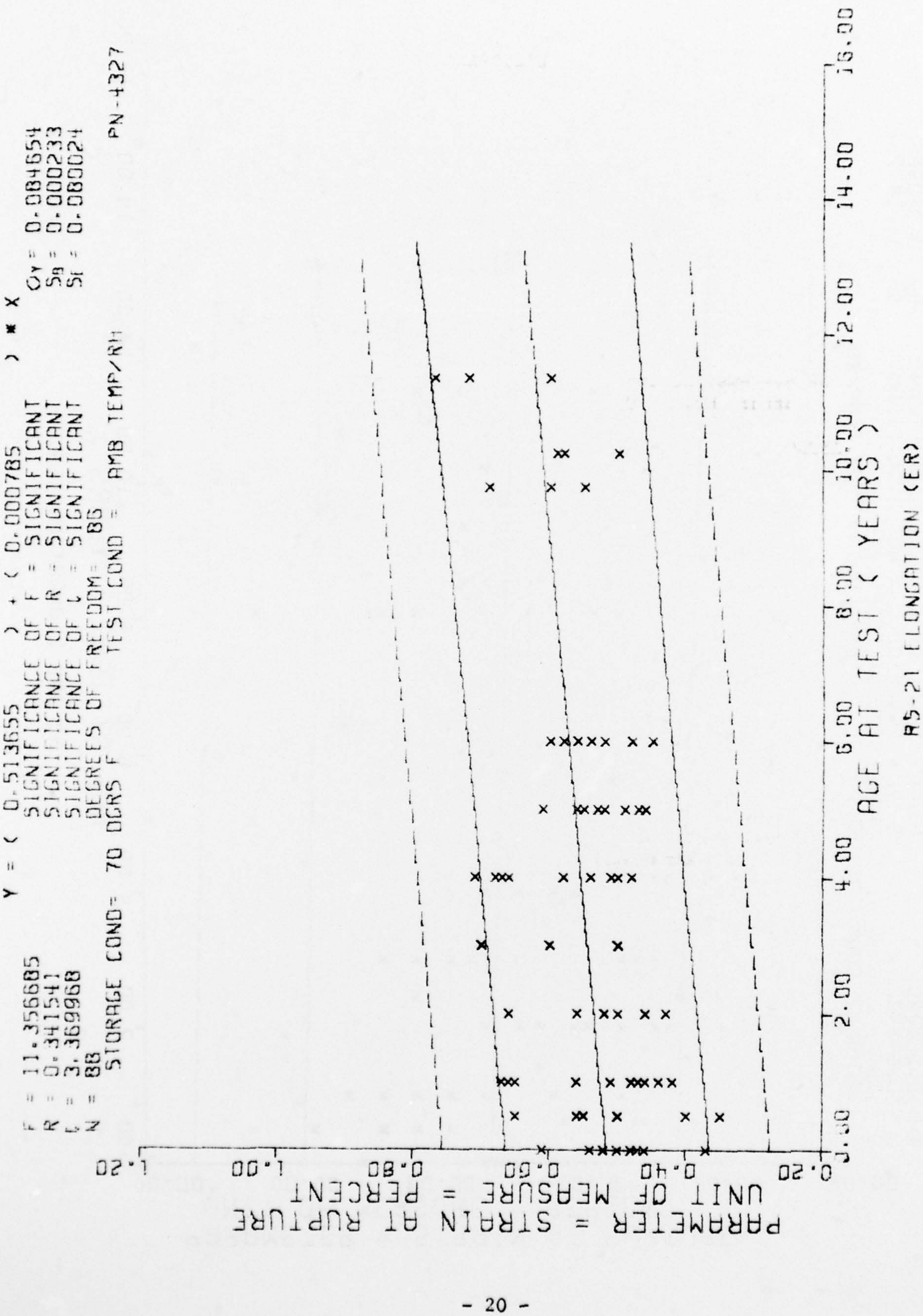

F = 11.356685
R = 0.341541
L = 3.369968
N = 88
Y = ( 0.513655 ) + ( 0.000785 ) * X
SIGNIFICANCE OF F = SIGNIFICANT
SIGNIFICANCE OF R = SIGNIFICANT
SIGNIFICANCE OF L = SIGNIFICANT
DEGREES OF FREEDOM = 86
STORAGE COND= 70 DGRS F
TEST COND = AMB TEMP/RH
σY = 0.084654
Sβ = 0.000233
Sε = 0.080024
PN-4327
PARAMETER = STRAIN AT RUPTURE
UNIT OF MEASURE = PERCENT
0.20
0.40
0.60
0.80
1.00
1.20
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST ( YEARS )
A5-21 ELONGATION (ER)

Figure 12

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statistical group.

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This constitutes final reporting on the laboratory testing program on component materials from the RIP Surveillance Program.